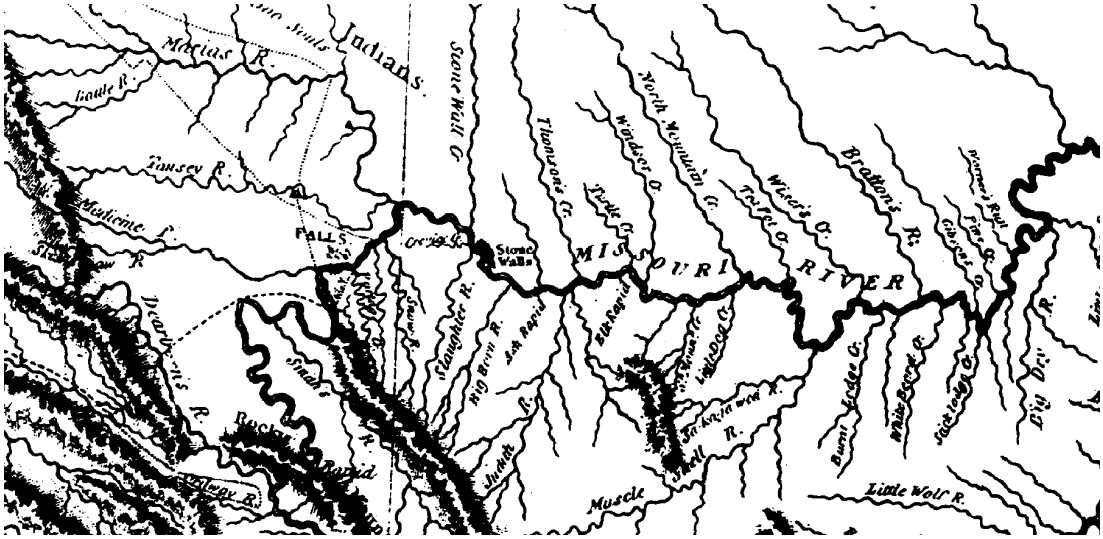
Chapter 1 Introduction



As the legendary Lewis and Clark Expedition approached the headwaters of the Missouri River in the Bitterroot Mountains of western Montana, a fork in the river impeded their progress. Captain Lewis held the belief that the north fork was not the main stream. He based his judgement on several remarkable pieces of evidence. The indians had advised the party that near the great falls, where the Missouri was known to begin, the water is nearly transparent. Also, they were told that as they neared the headwaters, the falls would lie a little to the south of the sunset. Although these facts favored the southern fork, the primary cue, that of the swiftest current, favored the north. Captain Lewis writes:

> These observations, which satisfied our [Captain Lewis' and Captain Clark's] minds completely, we communicated to the party; but every one of them was of a contrary opinion. ... The men, therefore, mentioned that, although they would most cheerfully follow us wherever we should direct, yet they were afraid that the south fork would soon terminate in the Rocky mountains, and leave us at a great distance from the Columbia. (Lewis & Clark, 1893)

After a short reconnaissance of the south fork, Lewis and Clark overruled the sentiments of the party at large and chose to turn south which was, as the story unfolds, proven to be the genuine Missouri.

Today, we are amazed at the ability of these men to navigate across an uncharted continent with nothing but a few rudimentary navigational instruments, some sketchy information from the natives, and their own experience to guide them.† In fact, from the migration of birds to the global positioning system, wayfinding in general has always been a topic of interest. This is primarily due to the fact that to some extent, everyone is familiar with navigation and disorientation. The tension that occurs with being lost, even for a moment, with no clues to find the way "home", can be profound. Kevin Lynch writes in *The Image of the City:*

> Let the mishap of disorientation occur and the sense of anxiety and even terror that accompanies it reveals to us how closely it is linked to our sense of balance and well being. The very word "lost" in our language means much more than simple geographical uncertainty: it carries a tone of utter disaster. (Lynch, 1960)

Yet, as much as this experience is one to be avoided, it is all too reminiscent of a typical virtual world experience. Virtual world navigators are well acquainted with disorientation and the anxiety associated with it. The stress of such an experience is just as real in a virtual world as it is in the real world.‡ Compounding the problem, virtual world navigators are often required to search for places and objects in a timely fashion as if the world were familiar. However, in many cases, virtual worlds are not revisited thus offering the naviga-

† The information the expedition received from indians was often incomplete and error prone due to the difficulty in understanding the different languages. Another note here is that often, as is illustrated in this anecdote, experience contradicts evidence. This was commonly the case where the expedition found itself trying to apply erroneous, region-specific (eastern North American) navigation principles to wayfinding problems in the Rocky Mountains and beyond.

tor no opportunity to learn from experience. In any case, virtual worlds typically offer no support for wayfinding. Those that do often supply assistance in an ad hoc fashion with no regard for the characteristics of the space or of wayfinding tasks in general.

The simple fact is, whether or not a designed and built space is real or virtual, it is a place; a place where humans will work, play, and spend their time, and in doing so, they must perform spatial tasks. Understanding this fact, research in architectural design and urban planning has produced wayfinding design methodology which can be used in coordination with traditional methods to help produce easily navigable spaces. This dissertation research is intended to advance virtual world design toward a similar methodology for application to computer generated spaces. The research is based primarily on environmental wayfinding principles and considers the relationship between wayfinding tasks and the environmental information on which successful completion of a spatial task depends.

Motivation

Problems associated with wayfinding have been encountered in every virtual environment laboratory in every large-scale virtual world. These problems may manifest themselves in a number of ways depending on the task being performed. Users may wander aimlessly when attempting to find a place for the first time. They may then have difficulty in relocating places just recently visited. Lastly, they may be unable to grasp the overall

‡ It could be argued that stress is greater in the real world because the tension subsides only when familiarity is regained whereas in a virtual world, it is possible to "quit" and end the experience rather than complete the wayfinding problem. In 1893, Elliott Coues wrote of the circumstances surrounding the decision at Maria's River:

> It is one thing to look at the country from a Pullman car; it was another to sight it from camp in 1805 — one thing to sit down in an easy-chair in front of a good map in 1893, and another to confront the Continental Divide in order to make a map, feeling that the success or failure of the Expedition, perhaps the life or death of the party, depended upon choosing one of two rivers which offered such a dilemma. Before the invincible explorers lay a thousand miles never trodden by the foot of a white man; behind them, two thousand miles of water-course through a howling wilderness; but there was that within them which rendered a correct decision at the mouth of Maria's river. (Lewis & Clark, 1893)

Clearly, the penalty for error could have been devastating. However, while there is no intent to argue for or against this point, it is important to note the fact here is that stress is present in either case and that, at the very least, completion of any navigational task when disoriented is dubious.

topological structure of the space. Any time an environment encompasses more space than can possibly be viewed from a single vantage point, these problems will occur (See Large-Scale Space on page 6).

Although disorientation and wayfinding problems are clearly evident in many virtual worlds, they are largely ignored in virtual world development. In those worlds which do address these problems, solutions are viewed as an engineering problem rather than a scientific problem; each case being solved independently of others in an ad hoc fashion. No solution to date has had a scientific basis allowing it to be applied logically to other problem domains.

This problem was addressed by the National Science Foundation at the Workshop on Research Directions in Virtual Environments at the University of North Carolina at Chapel Hill in 1992 (Bishop, Bricken, Brooks, Brown, Burbeck, Durlach, et al., 1992; Brooks, 1993). The need for research in navigational cues for virtual environments was also listed as one of the nine primary requirements of computer software for the advancement of virtual environment technology by the National Research Council (1995). Navigation was one of the primary topics addressed at the Workshop on Challenges of 3D Interaction at SIGCHI ‘94 (Herndon, van Dam, & Gleicher, 1994).

Conceptually, a virtual world is a space. Therefore, space, and the problems inherent to space, must be considered as an intrinsic part of the design process of large-scale virtual worlds.

Objective

Given that wayfinding issues present a fundamental problem to virtual world navigators of large-scale spaces, it is curious to note that not only is the problem ignored in virtual world design, but it is often given an equal lack of attention in architectural design and urban planning. It was this concern which prompted Kevin Lynch to investigate wayfinding as it pertains to urban planning in *The Image of the City* (Lynch, 1960). This study was followed by another focusing on architectural design by Romedi Passini in *Wayfinding in Architecture* (Passini, 1984). Both resulted in a set of design principles which could be

applied to design problems in their given domain to alleviate many wayfinding difficulties. The hypothesis of the research described in this dissertation is that these same principles will be effective in the design of virtual worlds. This assertion is based on psychological evidence suggesting that the foundation for these principles lies in cognitive theory and human spatial abilities and thus is independent of the type of environment to which it is applied.

This research is directed toward a methodology for the design of wayfinding augmentations to virtual worlds based on real-world wayfinding principles which will facilitate skillful wayfinding behavior in novices. Skillful wayfinding behaviors are characterized by the movements of the subject during wayfinding task execution (See Skillful Behavior on page 7). An expert exhibits observable purposeful, oriented movements whereas a novice will tend to frequently exhibit random, disoriented movements which do not promote task completion. The objective of this body of research is to develop and verify a set of wayfinding design principles on which such a methodology can be successfully founded.

Approach

This document will describe the results of an experiment which shows that real-world wayfinding principles are effective in designing virtual worlds which facilitate skillful wayfinding behavior. An extensive survey of the experimental psychology literature reveals a number of basic principles of human spatial abilities. In particular, the ways in which humans acquire, represent, and access spatial knowledge is discussed.

These principles are clearly represented in real-world design methodologies. As argued by Lynch (1960) and Passini (1984), accounting for natural human spatial abilities and shortcomings in environmental design can have a great payoff in the resulting space. Specifically, wayfinders of spaces which have been designed with their needs in mind, not only perform wayfinding tasks with greater ease and skill than in other environments, but accordingly, they report a satisfaction with the place and a generally high level of comfort with it. This investigation draws from this body of research as well in order to show how these design principles can be adapted and extended into the virtual world domain.

Definition of Terms

The following is a short list of important terms which will be used commonly in this dissertation. Because their definitions are often misunderstood or have more than one acceptable meaning, their use within the context of this research is given here.

Large-Scale Space

A large-scale environment is defined by Kuipers (1978) as

> a space whose structure cannot be observed from a single viewpoint. ... Naturally, this definition depends on the observer, so a city might not be large-scale when viewed from an airplane, while a map might be large-scale when viewed through a small hole.

This definition applies to large worlds such as continents and oceans (Darken & Bergen, 1992; Zyda, Pratt, Monahan, & Wilson, 1992), small worlds such as molecules when viewed at a large scale (Brooks, Ouh-Young, Batter, & Kilpatrick, 1990), and small worlds such as building interiors which cannot be viewed wholly due to occluding walls (Brooks, 1986; Funkhouser, Sequin, & Teller, 1992).

Navigation

Webster defines navigation as

> **navigate** *vb* [L *navigatus*, pp. of *navigare*, fr. *navis* ship + *-igare* (fr. *agere* to drive)] **1:** to travel by water: SAIL **2:** to steer a course through a medium; *specif*: to operate an airplane **3:** to get about: WALK **1a:** to sail over, on, or through **b:** to make one's way over or through: TRAVERSE **2a:** to steer or manage (a boat) in sailing **b:** to operate or control the course of (as an airplane)

Clearly, the origin of the term "navigation" is closely tied to actual directed movement making no mention of where the navigator might be going (or intend to be going). Therefore, it is to be distinguished from wayfinding.

Wayfinding

Wayfinding is focussed on the notion of spatial knowledge. It considers the task in question requiring that navigation (physical movement) take place. Passini (1984) describes it best.

> Spatial orientation and wayfinding ... allow people an idea of surrounding space, of their positions in that space, and they allow purposeful movement within that space.

In other words, wayfinding precedes or facilitates navigation. We will refer to navigation as a directed movement action and wayfinding as cognitive action involving route determination.

Orientation

From Passini (1984): The term “orientation”, according to its dictionary definition, has its root in “orient” and the custom in some cultures of situating certain buildings (usually churches or buildings with religious significance) or entrances mainly east. Webster concurs.

> **orient** [L *oriens, -entis* rising (sun)] **1:** to cause to face or turn to the east. **2:** to place or adjust, as a map, in exact relation to the points of the compass.

In the context of this research, orientation refers to the knowledge of directional information in relation to an environment. This knowledge can be absolute or relative in nature. Absolute orientation involves orienting with regard to a static coordinate system such as the familiar cardinal direction system of north, south, east, and west. Relative orientation involves orienting in relation to a point of reference. This same designation can also be applied to positional information (note: position and orientation are <u>not</u> the same). A position can be specified in terms of its absolute identification (e.g. as defined by a coordinate system) or relatively (e.g. to some reference point). See Figure 1-1.

Skillful Behavior

Card, Moran, and Newell (1983) define skillful behavior as

> competent, expert, rapid and accurate performance. This includes the sense of effortlessness—smoothly coordinated and pattered behavior—that is the visible hallmark of skilled performance. p. 358

In terms of wayfinding, skillful behavior is taken to be purposeful, oriented movement during navigation.

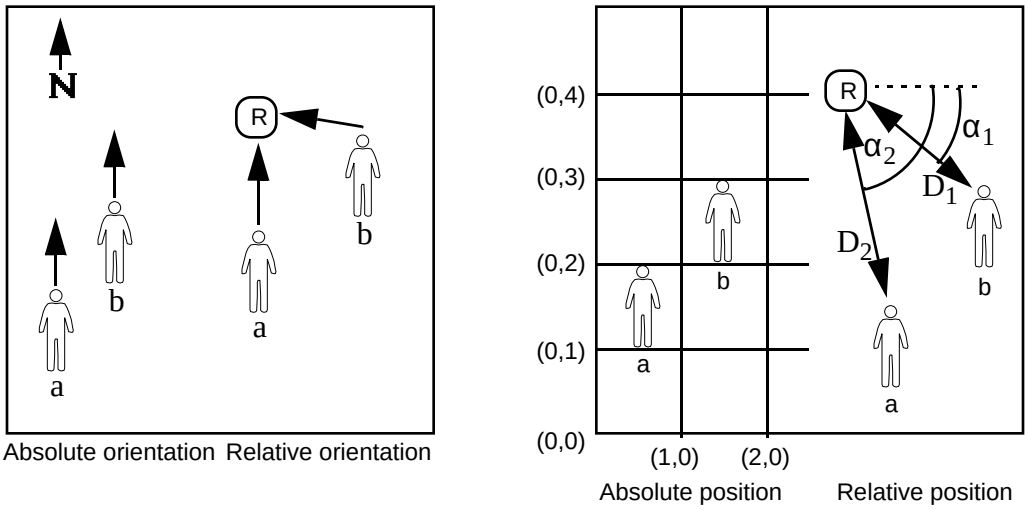


Figure 1-1 Absolute orientation with respect to the north direction. Relative orientation with respect to reference point R. Absolute position with respect to a Cartesian coordinate system with origin (0,0). Relative position with respect to reference point R defined in terms of a distance D and a relative angle α.